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Evaluation of Three Strains of Channel Catfish *Ictalurus punctatus* Fed Diets Containing Three Concentrations of Protein and Digestible Energy[1]

MENG H. LI AND EDWIN H. ROBINSON[2]

Delta Research and Extension Center, Mississippi State University, P.O. Box 197, Stoneville, Mississippi 38776 USA

WILLIAM R. WOLTERS

United States Department of Agriculture, Catfish Genetics Research Unit, P.O. Box 38, Stoneville, Mississippi 38776 USA

Abstract

A 3 × 3 factorial experiment was conducted using three strains of channel catfish *Ictalurus punctatus*, USDA102, USDA103, and Mississippi normal (MN), and three concentrations of dietary protein. Three practical diets were formulated to contain 25, 35, or 45% crude protein with digestible energy/protein ratio of 10.0, 8.1, or 6.8 Kcal/g, respectively. Juvenile channel catfish (mean initial weight: 15.1 g/fish) were fed the experimental diets twice daily to approximate satiation for 8 wk. Regardless of dietary protein concentration, the USDA103 strain consumed more feed, gained more weight, and converted feed more efficiently than other two strains. The MN strain consumed less feed and gained less weight than the other strains. Regardless of the strain of channel catfish, differences in weight gain, feed consumption, and feed conversion ratio were observed among fish fed diets containing various levels of protein with the 35% protein diet being the best. Neither dietary protein concentration nor strain had significant effect on fillet protein level. Data pooled by fish strain showed that fish of MN strain had lower fillet fat and higher moisture than fish of other two strains. Data pooled by dietary protein showed that fish fed the 45% protein diet had a lower level of fillet fat than fish fed the 35% protein diet, but this did not appear to be a strain effect, rather it was a result of decreased feed consumption. Results from this study clearly demonstrate that performance of the USDA103 strain of channel catfish was superior to other strains tested. The growth characteristics of the USDA103 strain of channel catfish make the strain a promising candidate for commercialization. However, data are needed on performance of the strain from fingerling to marketable size under conditions similar to those used for the commercial culture of channel catfish prior to their release to the catfish industry.

Research on channel catfish *Ictalurus punctatus* genetics and breeding began in the late 1960s and early 1970s (Dunham and Smitherman 1987); however, applications of genetic improvement in channel catfish culture have not had significant impact on commercial catfish production. Genetic improvement in domestic livestock is apparent in the poultry, beef and dairy cattle, and swine industries where genetic research, particularly in the areas of quantitative inheritance, has made major contributions to industry advancement and profitability. From 1930 to 1976, annual milk yield in dairy cattle increased 125% from approximately 2,000 kg/cow to 4,500 kg/cow. Since 1945, the time required to produce a marketable pig (100 kg) has been reduced from 200 to 160 d. In the poultry industry, producers have reduced the time required to produce a marketable broiler (1.7 kg) from 14 to 7 wk and have doubled feed efficiency (Warwick and Legates 1979; Gall et al. 1988).

Potential increases in production efficiency from catfish breeding are projected to be

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[2] Corresponding author.

larger than any increases in other animals (Smith 1991). Improving production efficiency in catfish culture from the use of improved germplasm is certainly possible, and production efficiency and economic returns in commercial production should be highly correlated with animals demonstrating superior performance for these traits. Channel catfish germplasm selected for and demonstrating improved performance in growth characteristics would therefore be more profitable to raise.

Strains of channel catfish used in research and commercial culture are based on origin rather than performance records (Dunham and Smitherman 1984). Strains that have been cultured in hatcheries or used in commercial culture generally have faster growth than wild stocks. In addition to growth, strains have also been shown to differ in feed efficiency, disease resistance, dressout percentage, environmental tolerances, and reproduction (Broussard and Stickney 1981; Dunham and Smitherman 1987; Tomasso and Carmichael 1991; Wolters and Johnson 1994, 1995). Many of these strain evaluations were conducted more than 10 years ago when stocking density was relatively low, so need to be repeated under current high-density culture conditions in several geographic locations. As part of an applied breeding program, catfish germplasm needs to be evaluated utilizing diets typically used in commercial culture to determine if any strain (genotype) × diet interactions exist. This study describes performance of three channel catfish strains cultured in aquaria and fed three levels of dietary protein.

TABLE 1. *Percentage ingredient composition (as-fed basis) of experimental diets.*

	Dietary protein (%)		
Ingredient	25	35	45
Soybean meal (dehulled, 48%[a])	15.0	46.4	73.6
Cottonseed meal (41%)	10.0	10.0	10.0
Menhaden meal (61%)	4.0	4.0	4.0
Meat and bone/blood meal (65%)	4.0	4.0	4.0
Cooked corn	21.3	20.8	2.1
Wheat middlings	42.4	10.0	0.0
Catfish offal oil	0.0	1.5	3.0
Carboxymethylcellulose	2.0	2.0	2.0
Calcium phosphate (dibasic)	1.0	1.0	1.0
Trace mineral mix[b]	0.1	0.1	0.1
Vitamin mix[b]	0.1	0.1	0.1
Vitamin C[c]	0.1	0.1	0.1
DE/P[d] ratio (kcal/g)	10.0	8.1	6.8

[a] Percent protein.

[b] Commercial available mixes that meets or exceeds vitamin and mineral requirements of channel catfish except vitamin C (National Research Council 1993; Robinson and Li 1996).

[c] Stay C, 15% ascorbic acid activity (TM, Hoffmann La Roche, Inc., Nutley, New Jersey, USA).

[d] Digestible energy/protein.

Materials and Methods

A 3 × 3 factorial experiment was conducted using three strains of channel catfish, and three concentrations of dietary protein. Three practical diets (Table 1) were formulated to contain 25, 35, or 45% crude protein with digestible energy/protein (DE/P) ratio of 10.0, 8.1, or 6.8 Kcal/g, respectively. The DE/P ratio was allowed to vary, because in practical feed formulation there is no way to adjust the ratio and keep dietary fat and fiber levels in the desired ranges. All known nutrient requirements of channel catfish were satisfied (National Research Council 1993). The diets were prepared according to the procedures described previously (Li et al. 1993). The diets were stored at −30 C until used.

Juvenile channel catfish were obtained from pond spawns at the USDA (United States Department of Agriculture) Catfish Genetics Research Unit, Stoneville, Mississippi, USA. Fish from the Mississippi-normal (MN) strain, representing a commercial stock, were originally obtained in 1989 as broodfish from Farm Fish, Inc., Louise, Mississippi, USA with broodfish parentage described by Dunham and Smitherman (1984). Fish from the control lines of two research strains from the USDA Catfish Genetics Research Unit were also evaluated. The USDA102 strain was developed through family selection for growth and disease resistance from the Red River strain originally collected in 1988 from the Red River, North Dakota, USA (Hudson Bay drainage). The USDA103 strain was developed through family selection for reproductive characteristics, growth, and disease resistance from broodfish obtained in 1992 from the Uvalde National Fish Hatchery, Uvalde, Texas, USA. Twenty fish of each strain were stocked separately into each of 45 110-L flow-through aquaria (5 aquaria/treatment). The aquaria were supplied with well water (flow rate: 1 L/min) and continuous aeration. Water temperature was maintained at 30 ± 1 C. A diel light:dark cycle was fixed at 14:10 h.

Prior to initiation of the experiment, fish underwent a 2-wk conditioning period during which they were fed Diet 2 (Table 1). After conditioning, initial fish weight from each aquarium was determined, which averaged 15.1 g/fish. There were no statistical differences in initial weight of fish among strains ($P > 0.05$). Fish were fed twice daily (0800 and 1600 h) to approximate satiation for 8 wk. Feed consumption was monitored at each feeding. Aquaria were cleaned weekly.

Fish in each aquarium were counted and weighed collectively every 4 wk. At the end of wk 8, five fish from each aquarium were sacrificed by an overdose of tricaine methanesulfonate (MS-222, Argent Chemical Laboratories, Redmond, Washington, USA). Fillets were removed from each fish and frozen at −80 C for subsequent proximate analysis. Individual fillets from five fish per tank were homogenized, and crude protein, fat, moisture and ash determined in duplicate by methods described by the Association of Official Analytical Chemists International (1995).

Analysis of variance, Duncan's new multiple range test, and contrast (Steel and Torrie 1980) were used to evaluate the treatment effects on weight gain, feed consumption, FCR, survival, and fillet protein, fat, moisture and ash. Percentage data were transformed to arcsine values (Steel and Torrie 1980). Differences were considered significant at $P \leq 0.05$.

Results

Regardless of dietary protein concentration, the USDA103 strain consumed more feed, gained more weight, and converted feed more efficiently than the other two strains (Table 2). The MN strain consumed less feed and gained less weight than the other strains. Regardless of the strain of channel catfish, differences in weight gain, feed consumption, and FCR were observed among fish fed diets containing various levels of protein with the 35% protein diet being the best. Mean survival of fish was 98% to 100% which was not different among treatments.

Neither dietary protein concentration nor strain had significant effect on fillet protein level (Table 3). Data pooled by fish strain showed that fish of MN strain had lower fillet fat and higher moisture than fish of other two strains. Data pooled by dietary protein showed that fish fed the 45% protein diet had a lower level of fillet fat than fish fed the 35% protein diet, but not fish fed the 25% protein diet. Significant interaction between strain and dietary protein was observed only for FCR.

Discussion

Data presented herein clearly demonstrate that performance of the USDA103 strain of channel catfish was superior to other stains tested regardless of dietary protein level. Differences in performance among strains were most pronounced in fish fed the 35% protein diet, which resulted in the fastest growth. When fed 35% dietary protein, weight gain of the USDA103 strain was approximately 35% to 45% greater than that of the USDA102 strain and the MN strain, respectively. This difference in weight gain can be attributed to the increased feed intake and feed efficiency exhibited by the USDA103 strain. Data from unpublished studies in which various strains of channel catfish were raised communally

TABLE 2. *Mean weight gain, feed consumption, feed conversion ratio (FCR), and survival of three strains of channel catfish fed experimental diets containing three levels of protein.*

Strain	Dietary protein (%)	Weight gain[1] (g/fish)	Feed consumption (g/fish)	FCR	Survival (%)
Individual treatment means[2]					
USDA102	25	42.4	94.9	2.25 b	100.0
USDA102	35	64.3	104.9	1.65 c	100.0
USDA102	45	48.0	100.9	2.11 b	100.0
USDA103	25	59.8	100.4	1.69 c	99.0
USDA103	35	87.8	115.9	1.32 d	100.0
USDA103	45	67.2	114.0	1.70 c	100.0
MN[3]	25	32.2	83.0	2.60 a	98.0
MN	35	59.6	101.5	1.71 c	100.0
MN	45	46.8	96.5	2.10 b	100.0
Pooled SEM[4]		2.5	1.7	0.09	0.7
Pooled means[5]					
USDA102		51.6 v	100.3 v	2.00 u	100.0
USDA103		71.6 u	110.1 u	1.57 v	99.7
MN		46.2 w	93.6 w	2.14 u	99.3
	25	44.8 z	92.7 z	2.18 x	99.0
	35	70.6 x	107.4 x	1.56 z	100.0
	45	54.0 y	103.8 y	1.97 y	100.0
Two way analysis of variance					
Strain		**[6]	**	**	NS[7]
Dietary protein		**	**	**	NS
Interaction		NS	NS	**	NS

[1] Mean initial weight of fish was 15.1 g/fish.
[2] FCR means followed by different letters are different (Duncan's new multiple range test, $P \leq 0.05$). Duncan's new multiple range test was not conducted if the interaction was not significant.
[3] MN: Mississippi-normal strain.
[4] SEM: standard error for mean.
[5] Pooled means within each column followed by different letters are different ($P \leq 0.05$, contrast). Contrast was not conducted if the main effect was not significant.
[6] **: significant ($P \leq 0.05$).
[7] NS: not significant ($P > 0.05$).

in ponds at the USDA Catfish Genetics Research unit support the thesis that the USDA103 strain exhibits superior growth characteristics. The only apparent difference in body composition among strains was that the MN strain contained less fillet fat than the other strains. It is doubtful that this is a genetic trait, but is more likely related to reduced feed intake and slower growth exhibited by this strain.

Response of fish used in the present study to dietary protein concentration followed a similar trend for all strains. Fish that were fed a diet containing 35% protein gained more weight and converted feed more efficiently than fish fed either the 25% or 45% protein diet. Under pond culture conditions, dietary protein levels as low as 24% to 26% have been shown to be adequate for maximum weight gain of channel catfish raised from fingerling to marketable size (Li and Lovell 1992a, 1992b; Robinson and Li 1993). However, since small channel catfish raised in the laboratory generally require a relative high level of dietary protein, it was not surprising that 25% protein was inadequate to support maximum growth under the conditions of our study. Gatlin et al. (1986) reported that fingerling channel catfish raised in the laboratory required a min-

TABLE 3. *Proximate composition of fillets (on wet basis) of three strains of channel catfish fed experimental diets containing three levels of protein.*

Strain	Dietary protein (%)	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Individual means[1]					
USDA102	25	17.3	3.3	78.3	1.12
USDA102	35	17.9	3.8	77.4	1.11
USDA102	45	17.7	3.0	78.1	1.09
USDA103	25	17.1	3.9	77.8	1.09
USDA103	35	17.1	4.0	77.7	1.06
USDA103	45	16.8	3.3	78.6	1.01
MN[2]	25	16.4	2.4	79.7	1.14
MN	35	17.5	2.8	78.4	1.11
MN	45	17.4	2.3	79.0	1.07
Pooled SEM[3]		0.33	0.27	0.39	0.02
Pooled means[4]					
USDA102		17.6	3.3 u	77.9 v	1.10 u
USDA103		17.0	3.8 u	78.1 v	1.05 v
MN		17.1	2.5 v	79.0 u	1.11 u
	25	16.9	3.2 xy	78.6 x	1.12 x
	35	17.6	3.6 x	77.8 y	1.09 x
	45	17.3	2.9 y	78.6 x	1.06 y
Two-way analysis of variance					
Strain		NS[5]	**[6]	**	**
Dietary protein		NS	**	**	**
Interaction		NS	NS	NS	NS

[1] Duncan's new multiple range test was not conducted because the interaction was not significant.
[2] MN: Mississippi-normal strain.
[3] SEM: standard error for mean.
[4] Pooled means within each column followed by different letters are different ($P \leq 0.05$, contrast).
[5] NS: not significant ($P > 0.05$).
[6] **: significant ($P \leq 0.05$).

imum of 29% protein for maximum weight gain. The fact that a growth depression was observed in fish when the dietary protein concentration was increased to 45% was unexpected. Mangalik (1986) found that feed consumption of channel catfish raised in aquaria decreased when the dietary protein level was increased from 27% to 39%. This did not appear to be the case in our study, since fish fed the 45% protein diet apparently consumed as much as fish fed other two diets. However, the FCR was markedly higher for fish fed the 45% which suggests that perhaps feed that was offered was not totally consumed and the uneaten portion was washed from the aquaria. This appears to be an unlikely explanation, since we routinely observed feeding activity of each feeding and a decrease in activity was not apparent in fish fed the 45% protein diet. The diet contained a higher level of soybean meal than typically used in commercial catfish diets, but diets containing as high as 65% soybean meal have been shown to be palatable to channel catfish (Li and Lovell 1992a). In addition, all diets in the present study contained 8% animal protein sources which are highly palatable. The increased FCR and decreased weight gain of fish fed the 45% protein diet is most likely related to a deficiency in digestible energy relative to the amount of dietary protein. This diet contained a DE/P ratio of 6.8; whereas, a DE/P ratio of 8 to 10 is considered to be optimum for channel catfish (National Research Council 1993; Robinson and Li 1996).

In conclusion, the USDA103 strain of channel catfish appears to have growth characteristics that make the strain a promising candidate for commercialization. However, our data should be considered preliminary since the study was conducted under laboratory conditions and for only a relatively short period of the life cycle. Prior to their release to the catfish industry, data are needed on performance of the strain from fingerling to marketable size under culture conditions and diets similar to those used for the commercial culture of channel catfish.

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